of numerous engines of that type are to be believed. The cycle, of course, was of the " single-acting " type, and it is interesting to note that the celebrated Willans engine operated upon a similar cycle, with the difference that the expansion of the steam took place generally in more than one cylinder.

All the types of engines just described worked with steam of very low pressure, and it is remarkable that although Watt was well aware of the economy given by expansive working, yet he steadily resisted the tendency to adopt higher boiler pressures, many of his engines working at a pressure of about 7 Ib. per square inch. Due principally to the work of Trevithick, pressures gradually rose, and the high-pressure non-condensing engine was introduced.

The next notable improvement was made by Hornblower, who invented the compound engine.

From a thermal point of view the chief advantage given by compounding is that the total range of temperature from the stop valve to the exhaust is divided into two or more stages, so that the variation in any given cylinder is less, and the losses caused by initial condensation are reduced. In modern engines, compounding is carried through two, three, or, in the case of some marine engines, even four cylinders, the initial working pressures with the latter being as high as 220 Ib. per square inch, and at the present moment it is proposed to increase the boiler pressure to 300 Ib. per square inch, and to divide the expansion of the steam into five stages.

The latest development in the thermal design of reciprocating steam-engine is known as the " Uniflow ". An entirely new cycle is used, which enables the steam, to be expanded in one cylinder only, with the same economy as is obtained with engines of the triple-expansion type.

With the usual arrangement the steam enters and leaves by the same passages, or, in the cases where there are separate inlet and exhaust ports, at the same part of the cylinder. The piston, cylinder covers, and the surfaces of the ports are in contact with, and are scoured by, the exhaust steam during the whole of the return stroke. They are

cooled much below the temperature of the inlet steam, with the consequence that a portion of this incoming steam is condensed, and therefore the following stroke commences with a mixture of steam and water in the cylinder.

As the pressure and temperature of the steam fall during expansion, some of the water is re-evaporated, partly by its own heat and partly by taking heat from the cylinder walls, but much of the heat restored escapes unused to the exhaust. In the case of a compound engine it would, of course, be used in the next cylinder, but from a thermodynamic point of view this process is very wasteful, as the heat is abstracted from the steam at the temperature of admission and restored at a lower temperature.

Fig. i shows an indicator diagram from a single - cylinder engine. Volume V shows the amount of steam present at cut-off as disclosed by the indicator. Volume V^ however, shows the actual amount of steam

which is present as a mixture of steam and water, therefore — shows the